SKETCHES OF OUR INFORMATION

AS TO

RAIL-ROADS.

BY THE REV. JAMES ADAMSON, CUPAR-FIFE.

ALSO,

AN ACCOUNT

OF THE

STOCKTON AND DARLINGTON

RAIL-WAY;

WITH

OBSERVATIONS ON RAIL-WAYS,

&c. &c.

(EXTRACTED FROM THE CALEDONIAN MERCURY.)

Newcastle:

PRINTED BY EDWARD WALKER, PILGRIM STREET.

1826.

SKETCHES, &c.

WE must look upon the employment of iron surfaces upon roads, as only the natural consequence of the continual attempts to improve them, and as a thing likely to have been often talked of, and predicted, long before the advancement of art permitted the adoption of a material so expensive. To derive the greatest benefit from the methods of conveyance in use at present, would require the presence, on our roads, of two kinds of surface, of which neither can be found in perfection in any intermixture of the two; yet, in the formation of a public road, there is an attempt to combine the two incompatible qualities of presenting a hard and smooth surface to the wheels, and a soft and rough one to the feet of the horse. It is an obvious improvement to allot separate spaces to the differing surfaces. The employment of hard-stone tracks, alternating with spaces covered by a softer material, appears to have been an early step towards this separation; but the most advantageous form of it is found in the modern iron rail-roads. It is generally considered, that the day's

work of a horse on a rail-road, will be about $7\frac{1}{2}$ times that of the same animal on a turnpike road; but I do not know that it has been accurately ascertained, what may be the proportional intensity of the resistance on the turnpike, in its best condition, or that we have at all the means of judging of the effect of substituting hard-stone tracks under the wheels. I should fear, that, though they may at first afford a tolerably appropriate surface, on which the resistance may be very much inferior to that presented by a turnpike-road, their good condition could not endure long. Every one must have observed the rounded form assumed by the upper surfaces of the square blocks with which streets are paved, and that the abrasion of the angles leaves ultimately a very irregular surface. The interstices will be found deeper in the direction across which the wheels generally move; since, from the elasticity of the paving material, and the ground which supports it, the angles of the stones are peculiarly exposed to the action of the wheels. We may expect that the same effect will be produced on stone-tracks; and that they will, to a certain degree, present an irregular knobbed or undulating surface, incomparably less advantageous for traction, than that of the more perfect material of the iron rail-ways.

The advantage possessed by stone-tracks in admitting the employment upon them of wheels of the ordinary construction, is shared by the plate or tram rail-road; and this renders that form superior to others, for many purposes. These tram-roads seem to be almost universally in use in the mineral districts of Wales. This preference is approved of, but without assigning any adequate reason

for it, by Mr Overton, an engineer of that country.* The only shadow of an advantage claimed for the system is, that it presents a greater resistance on descents where retardation is required. But this excess of retardation is continual; and it is certainly preferable to get rid of it, and to produce, from other causes, the required increase of resistance, only in those situations where it is necessary. Mr Wood† determines, from experiment, the relative resistance on the plate-rail and the edge-rail to be as 73 : 63; and if, as is probable, the rails in those experiments were swept clean, this proportion must be more in favour of the plate-rail than that likely to be afforded by the average performance upon them; for the greatest disadvantage of the plate-rail is, that it is so much more apt to retain upon it those substances which increase the resistance. The suggestion of Mr Tredgold,‡ that the angle formed by the plate and its ledge should be rounded off, will, I have no doubt, be found advantageous in practice, as it must tend to prevent the rubbing of the wheels upon the ledge.

The conclusion seems well established, that the edge-rail affords the most advantageous result, from the power employed upon it; but we still want, to a certain degree, the means of deciding on the comparative merits of the substances of which it is formed. I do not know that experiments on a great scale have as yet been made on any

* Account of the Mineral Basins, &c. of South Wales.

† A practical Treatise on Rail-roads, &c. by Nicholas Wood.

‡ A practical Treatise on Rail-roads and Carriages, by Thos. Tredgold. When the names of those gentlemen are quoted, the above are the works referred to.

rail-roads, except those of cast-iron; so that the effect of diminishing the number of joinings, by using the longer bars of the malleable rails, is not exactly ascertained. But no one who has been dragged over both of them, or has inspected them together, can fail to give the malleable rails a decided preference. Of their comparative durability we must speak with more diffidence, until the facts be ascertained by experience; but I do not imagine that there will be found ultimately much difference in this respect. I had an opportunity of handling part of a bar, referred to in a discussion on this subject in the Newcastle Courant about a year ago. It had been in use as part of a rail-road about sixteen years, and except that the edges of the upper surface were considerably rounded off by the action of the wheels, it exhibited wonderfully slight appearances of decay. The Bedlington patent rails are merely a copy in malleable iron, as closely as the manufacturing machinery will allow it, of that form which had been found most advantageous for cast-iron rails. There are two distinct parts of that form, for which it will be useful to have distinguishing names. The upper flat part, along which the wheel rolls, we may, from its analogy to the old wooden rails, call the *tram* of the rail; to the part projecting downwards from this, we may apply the appropriate designation of the *keel* of the rail. The keel is deepest in the middle between the two points, upon which the rail is supported. The vertical longitudinal section of the rail is, therefore, somewhat similar to the segment of a curve cut off by a chord. Now, as in the malleable rails, many such lengths are formed in one piece, the lower part has an undulating appearance; and the production of this

irregularity in depth, is one of the most ingenious parts of the beautiful process of their manufacture. As it is done by an eccentric groove in one roller revolving opposite to a concentric one in another, it is evident that this part of the process cannot be repeated; for the second attempt might merely shift the undulations to other parts of the bar. Besides the undulations thus produced in the lower part, there are slighter corresponding ones produced in an opposite direction, in the upper part of the rail. To straighten this upper surface, the rail is put several times through grooves in the rollers, which compress that part in all directions, but exert merely a lateral pressure upon the undulated under part. Thus, if there be any difference of texture in the different portions of the rail, the upper part will be more dense, and the under part will approach nearer to the condition of wire-drawn iron; and each will be of the nature best suited to resist the different kinds of action to which they are exposed. But as the whole process takes place on a short mass of iron, which is gradually rolled out to about six times its original length, and as the operation is finished before the metal has lost its red heat, it is not likely that there will be any perceptible difference of texture, or that, in uniformity or toughness, the rail will be in any way inferior to other malleable iron. There is thus little probability of the occurrence of that exfoliation which it is imagined will take place upon them by the effect of great pressure. Not the least appearance of it is to be seen on rails of this sort, which have had engines of about 7 tons in weight, in constant employment upon them for above two years.

The duration of the rail ought to be determined by the

period during which the upper part retains sufficient thickness to support the pressure of the wheel, without being broken or folded down; and if it be found, that, in the malleable rails, the under part decays too rapidly, then, as much iron must be added, beyond what is necessary for the due strength of the rail at first, as will enable the keel to retain its requisite strength and stiffness, until the upper part be worn away. Though somewhat of the strength and stiffness be lost, in a form of uniform depth, compared with that which is deepest in the middle between the points of support, when the quantity of iron is the same, it may perhaps be found advisable to relinquish the vertical undulations in the keel; in order that less surface and fewer angles may be exposed to the influence of moisture. This would be most advantageously effected, by having a keel of uniform depth, expanded into a cylindrical form at its under surface. We should also, then, have a neat and convenient method of attaching the rails to the blocks on which they rest: for a cast-iron chair or pedestal, formed so as to embrace this cylindrical part, might be slid on at the end of the rail, and pushed along to its proper place, where it would keep hold of the rail without pins or wedges. This sort of chair could be so formed, as to obviate, to a great degree, the consequences of the partial displacement of the blocks. The rail would have also the power of expanding longitudinally, without producing any derangement, and thus, on straight lines, very considerable lengths of the rail might be welded together, without inconvenience.

The breadth of the tram of the edge-rail is never, as far as I have seen, above 2¼ inches; and no such rule is

observed, as that which Mr Tredgold mentions, viz.—"That the breadth in inches should be twice the weight upon one wheel in tons." The rule is founded on the circumstance, that the loaded coal-waggons, in the neighbourhood of Newcastle upon Tyne, generally weigh 4 tons, and the rails are almost always about 2 inches broad,—but along the same rails roll the engines also, carrying about twice the weight of a waggon. In fact, the rails have been gradually increased to their present breadth, with the view of preventing them from cutting grooves in the wheels, and that breadth appears to answer well for the heaviest weights likely to be permitted on rail-roads.

The strange form of a rail-road, consisting of a single line of rails, supported on upright pillars, proposed by Mr Palmer, and recommended by Mr Tredgold, will, I suspect, be found applicable to few situations. It differs from others, in requiring not only room in breadth and height, but also a clear space of some feet below the rail. Thus, it cannot approach the surface of the ground without having a trench cut to receive it; and to secure a level line, must require either very high pillars in the valleys, or deep excavations through the hills. If it be not destitute of curves, the motion on it must be slow and regular, else the tangential force of the load will derange the structure; and if the pillars be inclined towards the centre of curvature, to counteract the effect of one velocity, that inclination will suit no other. If a continuous chain were attached to it, as Mr Tredgold proposes, it would meet with a very serious obstacle on all roads crossing it; for, except they should go over it by a bridge, it must proceed

at a very expensive height above them, as it would then be impossible for a carriage to go through it.

Mr Wood has made the nearest approach to the complete elucidation of the data necessary to determine the resistance upon rail-roads, and the power requisite to overcome it. The experiments made by Mr Tredgold for this purpose, do not appear to be of much value, and in his book they are narrated too vaguely, to lead the reader to any decisive conclusion. In those which he has described, for the purpose of shewing the proportional resistances with different loads, and different wheels, the weights which produced the motion seem to have been omitted in determining the mass moved; and the real resistance, independent of the accelerative force of the moving weights, is not calculated at all. In the two experiments, from which he deduces the real amount of the friction at the axle of the carriage, the proportion of the gravitating force, employed in accelerating the revolution of the wheels, was probably of sufficient amount to require alteration. Mr Tredgold remarks, that "he avoided the smoothness and accuracy of workmanship" in preparing his model, "which could not be adhered to in machines in use." Now, this forms the strongest objection to any reliance on his experiments; for no model can have that relative smoothness, and accuracy of workmanship, which is found in larger machines. In constructing coal-waggons, which carry about three tons, the minutest attention is generally employed to secure accuracy of form, and smoothness of surface, in the moving parts. I had an opportunity of observing the importance of attending to those circumstances, while assisting Mr Wood to make

some experiments at Killingworth, in August last. In applying some new bearings to new axles, though both had been turned and polished in lathes with the utmost care, yet the friction at the axle did not become constant, and reach its minimum, until the carriages had been dragged about heavily loaded, during a whole day. It requires attention to those circumstances, to account for the difference in the ratios of the friction to the weight, as determined by Mr Tredgold and Mr Wood, the one estimating the friction at double the amount which the other assigns to it.

In Mr Wood's table, representing the relative and actual resistances in different experiments, there is somewhat of embarrassing obscurity, arising principally from his not having narrated before, the whole circumstances of one of the series of experiments contained in it.* It is satisfactory to find, that the result of his two totally dissimilar methods of experimenting agree so closely. His deduction from them may apparently be depended upon in practice: That with wheels, of which the ratio of the diameter to that of the axle, is 12 : 1, the total resistance will be $\frac{1}{200}$ part of the weight of the whole carriage and load. I have had an opportunity of witnessing experiments, in which, by taking every precaution to obviate the causes of retardation, it was reduced very considerably beneath the lowest amount in Mr Wood's table. We do not yet know exactly what proportion the resistance arising from the contact of the wheel with the rail bears to the whole; yet, as it is evidently very small, and pro-

* Essay on Rail-roads, p. 195.

bably diminishes as the diameter of the wheel increases, we may decide, that the fraction $\frac{1}{18}$ of the weight expresses with sufficient accuracy the resistance at the axle, and that this quantity, divided by the number of times the diameter of the wheel contains that of the axle, will express the whole resistance, when the machinery is in tolerably good order. This, when the ordinary wheels, three feet in diameter, are used, amounts to about $11\frac{1}{2}$ lb. per ton; so that, if the constant progressive effort of any power be known, we can readily tell with how much it ought to be loaded on a rail-road.

There is a very great variety of opinion and statement with respect to the power of horses at different velocities. The experiments do not yet seem to be sufficient in number, and sufficiently varied, to afford unquestionable conclusions. The formula $(12 - v)^2$ seems to give the velocity corresponding to the maximum effect, a higher value than experience warrants. The Tables given by Mr Wood, of the performance of horses on the colliery railways, represent the effect of the horse as so very irregular, that they lead to no very satisfactory conclusions; because we do not know what effect such irregularities may have in influencing the amount of the work done. His statement, that the power of a horse travelling 20 miles per day, at the rate of 2 miles per hour, may be represented by 112 lb. is more probably under the truth than above it. Mr Tredgold has pointed out, that the general formula ought to include in it as an element, the length of time during which the labour is continued; and that, corresponding to each assumed duration, there is a velocity which produces a maximum of effect, and that this velo-

city must have a certain relation to that rate of motion which a horse can sustain unloaded, during the number of hours assumed for the duration of his labour. But the assumptions from which are deduced the numerical values of those velocities, are either unintelligible to me, or are totally inadmissible. There results from them the strange position, that the muscular force which can be continued for a day, has to the weight of the animal the ratio of 3.37 : 1, though in fact the true ratio is more nearly the inverse of this. If, according to Mr Tredgold's estimate, a horse could exert a constant force of 125 lb. during 6 hours, at the rate of 3 miles per hour, his day's work on a rail-road would, at the rate of $11\frac{1}{2}$ lb. per ton, be 10.8 tons conveyed 18 miles: according to Mr Wood's estimate, it would be 6.6 tons conveyed 20 miles. In these estimates, and in those of Mr Wood's table, p. 239, the weight of the carriage is considered as part of the load, and this in general is rather more than one-fourth of the whole weight.

These theorems express only the relation of the effort to the effect, on a dead level. On an ascent, not only must the resistance be increased, but wherever the moving power resides in a moving body, the effect of its effort must be diminished. Thus, a horse weighing 10 cwt. walking unloaded up an ascent of 1 foot in 33, would exert an effort nearly equal to that of dragging 1 ton on a level rail-road. The weight of the moving body is peculiarly worthy of attention, when locomotive engines are employed. In the theorems on this subject, as they are stated by Mr Tredgold, the weight of the engine is not admitted as part of the load; but it bears too great a pro-

portion to the whole load, to be safely neglected, and the introduction of it will be found to modify very greatly the practical conclusions to be drawn from the formulæ.

Let E represent the weight of the engine, and a be that fractional part of its weight representing the available friction which produces the progressive motion of the engine-wheels upon the rails; then E a will represent the engine's force of traction upon a level.

Let i be the angle of inclination;

W the weight of the waggons and load;

f the friction at the axle of the waggons when the pressure is 1;

n the diameter of the wheel when that of the axle is 1;

then we have the general equation to express the relations of those quantities,

$$E\,(a \mp \sin i) = W\left(\frac{f}{n} \pm \sin i\right).$$

The upper signs give the equation for ascending slopes, and the lower that required for descending slopes. W may be expressed by a multiple of E, and in that case we shall be able to find the inclination at which any required proportion of the work done on a level may be performed. If $\sin i = o$; then

$$E\,a = W\frac{f}{n};$$

and as, by Mr Wood's conclusions,

$$a = \frac{1}{25}, \text{ and } \frac{f}{n} = \frac{1}{200}, \text{ then } W = 8\ E,$$

or the proper load for an engine on a level is *eight* times the weight of the engine.

If we wish to know at what inclination the engine would retain only half its power, we may make $W = 4\ E$; then

sin $i = \frac{1}{250}$, or the ascent will be 1 foot in 250, or about 21 feet per mile. In this case, two engines would perform the work of one on a level. The use of two engines on such slopes, one acting in front of a train of waggons, and the other behind them, has been proposed by Mr Stephenson, of Newcastle upon Tyne; and where the inclinations are of considerable length, would form a most convenient method of surmounting them. If, in the general formula, we make sin $i = \frac{1}{250}$, and use the lower signs, we shall find that, at that inclination, one engine will travel down with *forty-four* times its weight, or eleven times the load which it could drag up the ascent. By the same formula, if the effort of a horse, at any velocity, be represented by $\frac{1}{10}$ of his weight, he will, on a level, drag twenty times his weight; and the inclination at which his load, with the same velocity, ought to be one-half, or only ten times his weight, is $\frac{1}{200}$. The effort of a horse in carrying a load, is assumed to have, to his power of traction, the ratio of 3 : 1; or $\frac{\sin\ i}{3}$ is substituted for sin i in the first member in the equation. This is on the supposition, that the friction of the carriages is as small as that which is created on rail-roads. If the friction on a common road amount to five times that on a rail-road, the load, in the same circumstances, will, on a level, be four times the weight of the horse; and the inclination, diminishing the load to one-half, will be $\frac{1}{46.6}$, or one foot in 47 nearly. Hence we see the necessity of diminishing the rate of ascent on public roads more than is generally done, as well as improving the surface.

The same formula will afford us the means of disco-

vering what ought to be the inclination of a rail-road, when the traffic in one direction bears a known proportion to that returning in the opposite one. If we make the ratio of these loads, expressed as multiples of the weight of the engine to be $q : 1$; then, taking the values of sin i from the equations, with the upper and lower signs separately, we have the resulting equation,

$$\sin i = \tfrac{1}{2} \times \frac{q+1}{q-1} \times \left(a + \frac{f}{n}\right) \pm \sqrt{\tfrac{1}{4} \times \left(\frac{q+1}{q-1} \times a + \frac{f}{n}\right)^2 - \frac{af}{n}}$$

If $q=2$, and the other symbols express the same quantity, as before,

$$\text{Sin } i = \frac{1}{666} \text{ nearly};$$

in this case $W=6$, and $qW=12$; or an engine which, on a level rail-road, drags eight times its own weight of loaded carriages, will, on an inclination of 1 foot in 666, drag up six times its own weight, and will drag down twelve times its own weight. If $q = 4$, which is nearly the proportion when loaded carriages descend and empty ones alone return, the inclination required is about $\frac{1}{361}$; in this case the weight dragged up ought to be nearly 4.8 times the weight of the engine, and that taken down the inclination ought to be rather more than nineteen times the weight of the engine. If $E = 7$ tons, the weight of the empty carriages will be about $33\frac{1}{2}$ tons, and the weight of the goods conveyed on them will be about 100 tons.

From the great effect which the weight of the engine and load, independent of their friction, has in diminishing the progressive effect on inclinations so small, we may perceive how little can be gained by enabling the engine to ascend greater inclinations; since we must make a great

disproportion between either the loads, on a level and on an inclination, or their velocities.

Before we can anticipate with any confidence the performance of an engine, we must know what part of its moving power is employed in the support of its own functions, independent of that expended on the object of its effort. Our knowledge of this subject is, I fear, very deficient with regard to most kinds of machinery, because the sort of effect which they are employed to produce, renders it difficult to estimate the power wasted upon it. It is to be hoped, that its great importance will secure greater attention to it, since the comparative advantage of many different forms of machinery can be determined only by the discovery of the comparative amount of power necessary to communicate motion through them. It is not easy to devise means for obtaining this object even in machinery much under our control, and we ought, therefore, to feel grateful to Mr Wood for having opened up to us some novel sources of information, likely to be productive of considerable certainty on the subject. The locomotive engine is a peculiarly manageable thing, since all its parts may easily be put in motion, without employing its ordinary moving power, and the effort required to put them in motion becomes easily ascertainable. Of this advantage Mr Wood has taught us to avail ourselves, and though we do not find in the detail of his experiments the means of settling the question completely to our satisfaction, we can anticipate important consequences from the prosecution of the method he has pointed out. What we have chiefly to regret is, the small number of the experiments which are of use in this inquiry.

It is evident, that, if the engine were allowed to descend an inclined plane, having the steam restrained from acting upon the pistons, we could, from the observed time of its descent, estimate the retardation by the movement of all its parts, were all put in motion by the revolution of the wheels: and, besides, there are some of those parts which we could detach; and thus, by the effect of those which remained, judge of the proportionate influence of each of them. Mr Wood has narrated an experiment made for the purposes of ascertaining the total friction of an unloaded engine; and from the additional retardation caused by it, when attached to waggons descending an inclined plane, he estimates the friction of its joints, axles, and pistons, to be no more than 213 lb. Now, the resistance, by the friction at the axles of the wheels, could not, according to the lowest estimate in the table of experiments or friction, have been less than 100 lb.; so that only 113 lb. remain as the retarding force of the pistons, and other parts of the machinery.

Another method of estimating this retardation, is afforded by the experiments with wheels of different sizes. It was found, that, by applying to the same engine wheels of different diameters, different results were produced by the same expenditure of motive force in the same time. The retardation being equivalent to a constant pressure acting through unequal spaces, must have required, to overcome it, an expenditure of force in proportion to these spaces, which are as the diameters of the wheels. The resistance opposed by the rubbing parts would, therefore, when 3 feet wheels were exchanged for 4 feet wheels, be diminished in the proportion of 4 : 3; or the observed

increase of effect from the same pressive power, must have arisen from the annihilation of one-fourth of the friction, by the addition of one-third to the diameter of the wheels. The increase of effect appears to have been equivalent to a force of 146 lb.;* and, therefore the total friction of the engine with 3 feet wheels amounted to 584 lb. If from this we deduct the 100 lb., which will represent the constant resistance at the axles of the wheels arising from the weight of the engine, we shall have 484 lb. as the measure of the resistance from friction, in all the other parts of the engine. The measure of this retarding force in the former case, when the engine was unloaded, was 113 lb. These two numbers cannot yet express the ratio according to which the friction increases as the load is augmented, for the friction created by the motion of the piston and piston-rod within the cylinder, cannot be affected by the load. Let c represent this constant quantity: then the remainders $484-c$ and $113-c$ may be assumed to have to each other the ratio of the pressures, to which the moving parts of the machinery, exclusive of the pistons, have been subjected. When the engine was unloaded, this pressure could arise only from the resistance of the piston. Now, if l represent the length of the stroke, and d the diameter of the wheel, then, the constant resistance c will be to the pressure upon the piston, which would counteract it, in the ratio of $1 : \frac{3.1416\,d}{2\,l}$, which is the ratio of the spaces passed over by the piston and the engine. When the engine is loaded and working with a pressure of 50 lb. per

* This is greater than Mr Wood's estimate, and is found by taking the $\frac{1}{200}$ part of the additional load the engine carried with the same fuel.

square inch of the pistons of two nine-inch cylinders, the whole pressure on the pistons will be 6367 lb., which, when diminished in the ratio of $1 : \frac{3.1416d}{2l}$, will be the pressure producing friction in the other parts of the engine; if $d=3$ and $l=2$, its numerical value will be 2702 lb. Part of this is absorbed by the constant resistance c; and, therefore, 2702-c will represent the effective load or pressure producing resistance in the rubbing parts of the engine when loaded. Hence, as the resistances are in the ratio of the pressures, we have $484\text{-}c : 113\text{-}c = 2702\text{-}c : c$ and $c=98.3$ nearly; therefore the resistances from friction when the engine was loaded will be 385.7, and when unloaded 14.7.

The steam pressure required to overcome the friction of the pistons in the cylinders will be therefore, $98.3 \times \frac{3.1416d}{2l} = 231$ lb. This result is remarkable, as it is very far below the theoretical value of this kind of resistance: since there will be probably about 100 square inches of rubbing surface in each cylinder, the resistance is not quite $1\frac{1}{4}$ lb. per square inch of rubbing surface.*

The resistance created by the friction of the whole machinery, may be expressed as a multiple of either the pressure of the steam on the piston, or of the load attached to the engine; and if the numerical values of the quantities in question were to be depended on, we should be able to tell exactly either the steam power and weight of

* It would be interesting to know what pressure will render oiled hemp, or such substances as are used in packing the piston, impervious to steam. The experiment could be easily made, by exposing the substances (compressed between drilled plates) to the pressure of steam of different elasticities.

the engine necessary to carry a given load, or determine correctly the load which any given steam power could overcome. We are perhaps most in doubt respecting the relation between the weight of an engine and its power, or between the size of the boiler and the force of the steam which it can be made to afford. As there is a certain velocity of the piston which produces a maximum of effect, it is clear that this velocity alone should be preserved as much as possible, and the velocity of the load should be determined by the machinery, independent of that of the piston. Each engine ought, in fact, to be constructed for one determined velocity; and as the diminution of the engine's power by its friction, increases as its weight increases, it will be less expensive to have light engines and high velocities. None of those, as yet in use, have been intended to travel faster than six miles per hour. The highest velocity which I have witnessed was about twice this; but then the force of the steam was lost on account of the excessive velocity of the piston—there was no load to be overcome except the friction of the engine; and even this was diminished by the engine-man assisting to open and shut the valves. The experiments by Mr Wood, from which an estimate has been drawn of the travelling engine's work, cannot by any means give too favourable a measure of it: for the progressive effort of the engine, or that part of its power exerted on the load, must, on account of the undulation of the road, have varied in the ratio of 1 : 8, and there must have been a corresponding variation in the rate of the piston. Such inequalities in the load, and in the velocity of the machinery, are a disadvantage attending the application of steam power to

rail-roads in every form, except when a dead level can be secured. The greatest irregularities would be found, when a fixed engine was made to work over a considerable extent of country, if such a thing were possible. But the applicability of this method of using the steam-engine must be reduced far within the limits which Mr Tredgold assigns to it. The risk of interruption, in the traffic of a whole line, by the failure of one engine, is almost decisive against the system; and, besides this occasional inconvenience, there would be the constant one of being obliged to have at one time, on a long line of road, no more than that quantity of goods which the ropes or chains were calculated to bear, while no other power could be employed on the same line to remedy its failure or add to its capabilities. The great and continual expence of renewing the exposed parts of the machinery, in addition to these inconveniences, ought to be a good reason for preferring even very expensive excavations to this method of avoiding them.

We could bring the fixed engine and the locomotive engine more directly into comparison, if we could tell exactly the loss of effect incident to each, in moving a given weight over a certain space. Whenever the friction of the rope or chain and its rollers becomes the same proportional part of the load, as the locomotive engine's friction is of its load, we may consider this waste of power as equal. Mr Wood's experiments on inclined planes afford us the means of approximating to a decision on this point, though we must regret that the instances of the kind required are too few, and too little varied, to lead us to certainty. If we compare Nos. 14. and 15. of these experi-

ments, we find that the friction of a rope of a certain length, is represented in these two cases by the numbers 239 lb. and 250 lb., of which the difference is 11 lb. Now, this rope was, at the upper end of the plane, bent round a large fixed pulley or friction-wheel, the resistance to the revolution of which, independent of the friction produced by its own weight, we may assume as increasing in proportion to the tension of the rope; but from the manner in which the rope acts on the other friction rollers, the retardation caused by them may safely be assumed as constant. By examining the details of the experiments, we find that the tension of the rope, in the 15th experiment, was greater than it was in the 14th, in the proportion of $1 + \frac{1}{5.27} : 1$. This determines what fractional part of the friction of the large wheel, the difference of 11 lb. will amount to; and we will thus have 11×5.27, or 58 lb. as the resistance presented by the large wheel with the lighter load. The friction of the wheel caused by its own weight, will, by Mr Wood's rules, amount to 14 lb., and thus 72 lb. will be the total friction of this part of the machinery; if this be subtracted from the total resistance of the rope, rollers, &c. it will have 147 lb. as the friction of the rope, and the smaller rollers on which it rests. This is at the rate of 362 lb. per mile, and equal to about one-fifth of the strain to which the rope was exposed; and therefore the utmost strain to which, from this example, a similar rope ought to be exposed, is the friction of five miles of rope of the same thickness, resting on the same proportion of rollers of the same weight. If we make m represent the distance at which the expenditure of power

in overcoming the friction of the rope by the fixed engine is equal to that expended by the locomotive engines, in moving themselves, and let t represent the strain upon the rope, or power of the fixed engine, independent of its own friction, $\frac{t\ m}{5}$ will be, in this case, the resistance of the rope of the fixed engine, and will represent the friction of the locomotive engines; and, assuming that their friction is half the power available to move the load, or one-third of the power of the engine, then $\frac{t\ m}{5} = \frac{t}{3}$; hence $m = 1\frac{2}{3}$, the distance in miles. As the uncertain amount of the friction of the fixed engine and its rope-roll has not been taken into account, we may perhaps conclude, that the moving of goods by means of a rope of a greater length than $1\frac{1}{2}$ miles, will always be more expensive than their conveyance by locomotive engines, when there is no ascent on the line. To find the more general formula for an ascent, we must make the gravitating force of the load and of the rope to become elements in the equation. Now, as the weight of the rope per mile is nearly three times the strain to which it is subjected, making sin i to represent the inclination, $3\ t \sin i$ will be the gravitating force of the rope: hence $m \times \left(\frac{t}{5} + 3\ t \sin i\right)$ will represent the whole loss of force incident to the fixed engine, from the weight and friction of the rope. Now, as $\frac{2}{3}\ t$ is the progressive effort or adhesion of the locomotive engines, $25 \times \frac{2}{3} t$ will be their weight; and the loss of power incident to them, which is to be equal to that

lost by the fixed engines, according to the foregoing deductions, will be $\frac{t}{3}\left(1 + 50 \sin i\right)$; hence,

$$m = \frac{5}{3} \times \frac{1 + 50 \sin i}{1 + 15 \sin i};$$

which is the same equation as before, when $\sin i = 0$. When $\sin i = \frac{1}{25}$, then $m = 3.125$; in which case, the power of the locomotive engine ceases, and the resistance of the rope becomes equal to the whole strain placed upon it. This must be considered as, on those conditions, the limit of the length of a stage between two fixed engines, and since a chain of short links, of the same strength as a rope, would be heavier, and would require heavier rollers, but would not acquire so great an excess of strength, to compensate for its wasting, the substitution of it would probably make no great change on the results.

It appears, then, that if a line of road were *worked* by fixed engines, the number must be very great; and though certainly the expenditure of power, on a given conveyance, may be rendered less than is required by locomotive engines, provided the distances between the stations be less than those determined by the preceding rules, yet, when we consider the many inconveniences to which the employment of them subjects us, we must conclude that they should be resorted to only when other means are inapplicable. They possess no peculiar advantages, as to safety, to counterbalance those defects; any danger arising from liability in the carriages to be overturned, or from swiftness of motion, should the machinery be suddenly stopped, will be the same in both cases, or will be increased by the employment of fixed engines. Carriages

containing any persons, or any property easily injured, may be kept at a safe distance from a travelling engine, so as to be unendangered by its casualties, and easily brought to rest, before reaching it; but would be exposed to a dangerous concussion by a pause in the machinery of the fixed engine. The locomotive engines must certainly be high-pressure engines, but, from their size and treatment, are far more likely to be deficient in the power of generating steam, than able to spare any for explosions. There are circumstances, also, which render the employment of the high-pressure engine less dangerous in this form than in other cases. The distance at which it may be made to act, will render injury very improbable to all, except those in immediate attendance on it; and the slight oscillatory motions, to which the machine must always be liable, may be employed to keep the safety-valves from becoming fastened or rusted in their sockets.

For this purpose, it is only necessary to detach the valve from the lever, upon which the principal compressing weight is hung, and giving it the shape of a ball resting in a socket, to attach to it a considerable weight, hanging like a pendulum inside the boiler. This interior weight may also be so disposed as to give intimation of over-feeding with water, as the fluid, when it reaches the weight, will buoy it up, and help to open the valve. The method of conveying the heat through the boiler in a longitudinal tube, completely surrounded by the water, appears best fitted for deriving from the fuel all the advantage it can afford. A cylindrical tube has hitherto been used in the locomotive engine; but there are other forms which would expose more surface to the action of the

flame, with equal security against the pressure within. Probably this pressure may even be converted into the means of safety. If the tube were elliptical, and on that account ready to yield in one direction sooner than another, this yielding may be employed to pull open a valve, and allow the steam to escape, when the pressure approaches to any dangerous intensity. The whole apparatus of the engine is susceptible of numberless different forms; and it is not too much to expect, that the mechanical knowledge and ingenuity of our countrymen will lead them to many more perfect than those yet in use. As far as I know, none has yet worked so advantageously as those constructed according to the patent of Messrs Stephenson and Losh, Newcastle upon Tyne, and employed at the collieries of Killingworth and Hetton, in that neighbourhood.

The estimates of the expence of the employment of steam power upon rail-roads, do not seem in its favour, when compared with horses moving at the velocity most favourable to them, provided the cost of coals continues to bear the same ratio to the expence of supporting horses as it does at present in those districts of the kingdom where such constructions are likely to be advantageous. Where coals are 10s. per ton, the total expence per annum of a locomotive engine, including allowance for wear and tear, and interest on its value, will be £330; the work done will, if estimated by their performance at Killingworth, be 126,000 tons conveyed one mile in 312 days. The performance at the Hetton colliery, during the same period, amounted to 198,000 tons conveyed one mile. The difference arises from the greater regularity of the

line in the latter case. The effect, in the one case, is equal to somewhat more than that of three horses; and, in the other, somewhat more than four. The expence of neither of which, including that of their attendance, is likely to amount to the annual cost of the locomotive engine. But as the velocity in those cases is not much above the ordinary rate at which a horse travels, this may be looked upon as far under the rate of performance they are capable of attaining to. For few of the items composing the whole expence, are increased by increasing the speed of the engine, while its performance must increase in the rate of the velocity; so that a rate of speed may be found at which conveyance by them, will be cheaper than by horses moving at the velocity most favourable for their action. But the great advantage of steam-power lies in the economy with which quickness of motion may be produced. According to Mr Wood's estimate, an engine, which, at the velocity of two miles per hour, performs the work of four horses, will, at the rate of six miles per hour, perform the work of twelve horses. The increase of expence consequent on the increase of velocity, has not yet, I imagine, been correctly ascertained. It is evident, however, that it cannot approach to the ratio of the performances at the higher and lower velocity. It is well understood, that goods can be conveyed at a slow rate on a canal much cheaper than by any other method; and that as the motion is made quicker, the superiority of the canal vanishes; but in comparing them with rail-roads, the rate which produces equal effects with the same power has been stated at different values, generally, however, lying between three and four miles per hour, and varying

with the shape of the tracts and size of the canal; for all velocities beyond this, the advantage of the rail-road augments in a high ratio. The system of water conveyance we must look upon as nearly perfect; and the other as yet offering many chances of improvement; and from its applicability in some of its many forms to all imaginable situations, and its success in those wherein it has been attempted, we must esteem it eminently worthy of having its properties more accurately investigated.

STOCKTON AND DARLINGTON RAIL-WAY.

[EXTRACTED FROM THE CALEDONIAN MERCURY.]

EVER since the completion of this great work, the opening of which excited such attention, not only in this country, but throughout Europe, the public have been looking for information as to its operation and success, and we have recently, as already stated, learnt some interesting particulars on these points, which, as they throw new light on the advantages and effects of rail-ways in general, we are happy to be able to communicate to our readers, premising with a short account of the situation, extent, and other circumstances useful to be known regarding this rail-way.

The Stockton and Darlington rail-way was undertaken chiefly with the view of opening up the coal fields which lie in the south-western parts of the county of Durham. These form part of the great coal district of the north of England, that stretches throughout the counties of Northumberland and of Durham, in the shape of an irregular oblong, of which the central part lies along the banks of

the Tyne, from its mouth to about 20 miles up the river, and the extremes diverge about 30 miles to the north and south, diminishing continually in breadth till they terminate in the upper part of the Tees on the south, and at the mouth of the little river Coquet on the north. They are distant about 12 miles NW. of Darlington; 24 W. of Stockton; 13 SW. of Durham; and 30 miles SW. of Newcastle; and being situated on the extreme verge of the coal basin, where the coal approaches the surface of the ground, are hence capable of being wrought with facility; while in the neighbourhood of Newcastle, and along the banks of the Tyne and the Wear, which form the central parts of the mineral deposit, the coal lies at great depth, and the expence of sinking new pits to meet the increasing consumption is enormous. There, it requires the lapse of years, and an outlay of at least £100,000, ere an atom of coal can be extracted; but in the more remote parts of the Durham coal field a pit may be sunk and coals of good quality dug out for sale in the space of a week. All that was wanting, therefore, to render this district productive, was an opening to the great markets of the country, and with this view the railway was projected, to connect it with the thriving towns of Darlington and Stockton, and above all, with the shipping port at the latter place.

It commences at the Witton Park and Etherley Collieries, about two and a half miles to the north of West Auckland, and within a mile of the right bank of the Wear, which is here but a small stream, being upwards of thirty miles from its mouth. From thence it runs nearly in a straight line to West Auckland, and continues

bending to the east for about six miles farther, passing half a mile to the north of Brusselton Tower, and between West and East Thickley, till it approaches within a mile of the great road from London to Edinburgh, at a place termed the Traveller's Rest, about six miles to the north of Darlington. Here it turns quickly round to the south, and runs in a direction nearly due south, and parallel with the London road, to within a mile of Darlington, where it again bends to the east, crosses the London road, and the river Skerne, on which Darlington is situated; runs eastward almost three miles, turns southward again for another mile, which brings it into the valley of the Tees, and within a mile of the river itself; it then returns to the eastward, and runs parallel with the course of the Tees, until it arrives at Stockton, and terminates at the shipping places on the left bank of the river, which is here navigable for vessels of 150 tons burthen. The distance from Stockton up to Darlington, is about 12 miles—to the bend opposite the Traveller's Rest, 17½ miles—to the foot of Brusselton Hill, 20 miles—to West Auckland, 22 miles—and to Witton Park, the whole length is about 25 miles. In point of level, the line of road is pretty favourable, excepting along the first five miles at the upper end, where, the country being hilly, the line is irregular. It commences in the valley of the Wear, at an elevation of 470 feet above the level of the sea. Between this valley and the river Gaundless, a branch of the Wear which flows by West Auckland, and joins the main stream at Bishop Auckland, a ridge of high ground termed Etherley Hill intervenes, which it is necessary to surmount. This rises to 646 feet above sea level. From the top of this

height again the valley of the Gaundless presents an extensive tract of low land, crossing the course of the railway, and of such width and depth as render it impracticable to be filled up by embankments. The ground here falls to 320 feet. Here, therefore, the line descends into the valley, and rises again about half as high on the opposite side, to the top of another ridge of high ground which forms the north side of Brusselton Hill. It rises here to the original altitude of 470 feet, from which it again descends a little, until it falls into a more level country, which continues through the remaining 20 miles of its course, the line from the foot of Brusselton Hill to Stockton forming mostly a varying, but continued and gentle descent the whole way. Irregular as the above line may seem, great pains have been required, and no small expence, in smoothing down the inequalities of the country through which it passes, and forming the line into its present shape. For this purpose long and deep cuts have been undertaken without scruple; and vast embankments, one of which, in particular, at the foot of Etherley Ridge, is no less than 40 feet high.

From the above irregularities in the upper parts of the road, different methods have been resorted to for effecting the transit of the coal along the line. From the collieries at Witton Park and Etherley the coal waggons are conveyed by horses to the foot of Etherley Ridge, a distance of a mile. Here the horses are detached, and the waggons drawn up the north side of the ascent by means of a steam engine which is fixed on the top, and draws a rope that reaches from it to the foot of the hill, where it is attached to the waggons, and raises them along

with it. The distance from the bottom to the top of the hill is about half a mile, and the rise about 180 feet perpendicular. It is such steep ascents which are known in rail-ways by the name of *inclined planes*, and this one is termed the Etherley North Inclined Plane. At the top of the hill the waggons are attached to another rope, which is of such a length as to reach the low ground on the south side, a distance of upwards of a mile, with a descent of 312 feet. Down this second plane, termed the Etherley South Plane, the waggons descend by their own gravity, and the rope which is attached to them, winding round a barrel at the top, serves to regulate and check their rapid descent, as well as to bring up in their place a similar number of empty waggons returning from Stockton to the collieries, these waggons being afterwards let down the north side of the ridge, by means of the same rope which brought the full ones up from the collieries. The Etherley South Plane lands the waggons at the turnpike road at West Auckland; and from thence a new set of horses draws them about a mile and a quarter farther, to the foot of Brusselton Hill, up which the waggons are again conveyed by a long rope and fixed steam engine at the top, in the same manner as on Etherley Hill, and are again let down to the foot of the hill on the east side; these ascents and descents forming the Brusselton West and East Inclined Planes. The ascent up the former is upwards of a mile in length, and 150 feet perpendicular. The descent is less than half a mile, and about 90 feet perpendicular. From the bottom of Brusselton Hill, no farther interruption occurs in the line, and the waggons can be thence drawn all the way to Stockton either by

horses or by locomotive engines. The descent, however, varies in different places, from a perfect level to a descent of 1 in 104. This rail-way forms throughout only a single line, with three or four passing places in every mile, by which one set of waggons can pass clear of another. The rails are mostly of malleable iron patent rails from Bedlington iron works, which, from their great length and other advantages, have in this, as in other instances in which they have been tried, proved the best form or material in use. The whole expence of the rail-way has amounted to about 150,000l.

Such, then, is the nature, extent, and peculiar circumstances of this rail-way. The facilities which it presents for the transport of coals, or other materials or goods, are immense. On a common turnpike road it is well known a horse seldom draws more than sixteen cwt. or a ton; but on the level or slightly descending parts of this line a single horse can draw with ease four waggons, containing each a chaldron of 53 cwt. of coals, besides the weight of the waggon itself, of 24 cwt., in all nearly 16 tons, travelling with this at the rate of three miles an hour, and going at an average 24 miles a-day, but frequently making a trip from Brusselton to Stockton and back again, a distance of forty miles. The above is the performance in the lower parts of the line, where, however, the descent is in many parts far from being the most favourable for returning with the empty waggons. It is important to remark, that in another part of the line, namely, the flat between the Etherley and Brusselton planes, a single horse draws double of the above load, or upwards of 30 tons, owing chiefly to the short distance,

and the uniform and gradual descent. Up the steep ascents of the inclined planes, again, the fixed steam engines, of which the Etherley engine has a power of 30 horses, and the Brusselton of 60, draw eight loaded waggons, equal to 21 tons of coal, and ten tons in the weight of the waggons, in all 31 tons, and this at the rate of from eight to ten miles an hour. But it is the locomotive engines which shew, in the most striking light, the extent of power which the rail-way system places at our command. Each of these machines, of which there are two constantly at work, and one, if not two additional in preparation, draws after it 20 waggons, and frequently 24, each loaded as above, and forming in all a mass of 77 tons in the one case, and 92 in the other; and this enormous load is now regularly conveyed by each of these engines from Brusselton plane to Stockton, a distance of 20 miles, in four hours; the engine returns again in five hours with the empty waggons; and, including an hour spent in stoppages, completes the journey in ten hours; so that, if necessary, it could easily make two trips in one day and night, and thus deliver into the ships between 500 and 600 tons per week, which is equal to the work of 12 or 14 horses in the same circumstances.

In our last paper we endeavoured to describe, generally, the nature and objects of this important undertaking, with its situation, extent, direction, and other local and peculiar circumstances regarding it; and we were proceeding to give an account of the facilities which it affords for internal trade, and of the extraordinary loads which can be transported along it by the power, either of animals or machinery. The great obstacle, it is well known, to the

transport of goods or other commodities, arises from the irregularity and roughness of our roads, the surfaces of which present a series of little eminences, over which the carriage must be continually dragged, as it advances in its course. It is not merely the inertia of the mass which is thus to be overcome in impelling the carriage, and which every one knows forms no obstacle at all, excepting only at the moment of starting. When once the carriage or body, whatever it be, is set in motion, it would go on without any farther effort, if it met with no obstruction on the way. Along our roads, however, as experience shews, it requires a continued exertion to keep the carriages in motion, and the reason is, that they are subject not only to a progressive motion, but also to one of continued ascent and descent over the inequalities of the way. Our roads, no doubt, with the modern improvements, appear now remarkably smooth; but still, when carefully examined, they will be found, in reality, full of asperities, which, though minute to the eye, still constitute real elevations and depressions, on which the carriage, as it advances, is continually rising and falling; and it is the incessant lifting of the whole mass over these protuberances which chiefly constitutes that drag we experience, even in the smoothest of our turnpikes. The great object of a rail-way, therefore, is, to remove all these obstructions along the road, and this it does by laying tracks so uniform and smooth in their surface, that the carriage rolls along entirely free from that undulatory motion which, in ordinary cases, forms such a complete waste of our powers of draught. Simple as this idea is, its execution is by no means easy; it is attended with great ex-

pence, and requires, moreover, a highly improved state of the sciences and arts to give full effect to the principle. It is only, therefore, in a country like ours, with an overflowing capital, and abounding in intelligence and practical skill, where such a scheme can be thought of, however well the nature and elementary principles of the design may be understood and valued, as they have been indeed among men of science for a long time back. Accordingly it was not until the middle of the seventeenth century, that we find any traces of the art of laying railways. It then appears to have been introduced in a very rude way among the collieries in the neighbourhood of Newcastle, where the immense traffic in conveying coals from the pits to the places of shipment on the Tyne, rendered any contrivance of the kind of peculiar utility and value. Since that time it has been constantly in use, and receiving from time to time continual improvements, with the progress of the different arts on which it depends for its perfect construction; and it is remarkable that in proportion as these improvements have been introduced, the means of conveyance have been invariably increased. Every change which has contributed in any degree to render the way more smooth, even, and continuous in its surface, whether by introducing harder, smoother, or more durable materials than formerly; or seeking out and forming a more solid basis for these to rest on; or uniting the different pieces with closer or more perfect joinings, has in exact proportion, by easing the draught, added to our powers of tracktion. The first rail-ways, which were of wood, although much superior to the roads then in use, were probably inferior to the present turnpike roads, on

which a horse draws about 15 cwt. at an average. Such, however, is the perfection to which the art has now arrived, that, as was previously stated, a single horse on the level or slightly descending parts of the Darlington rail-way, the effect being no doubt partly aided by the descent, can draw a weight of 16 tons, *i. e.* as many tons can be drawn on the rail-way as cwts. on a common road; and each of the locomotive engines draws a weight of 90 tons, and can convey from Brusselton to Stockton, a distance of 20 miles, and deliver into the ships, from 500 to 600 tons of coal weekly.

With such prodigious powers of locomotion and trackage, no wonder that the expences of transport should have been greatly reduced; and to such an extent has this been effected, that the company have actually let the haulage of their coal, they furnishing the engines and waggons, at $\frac{1}{4}$d. per ton for each mile, which price is understood to pay the contractors well, and the company themselves are enabled to carry coals from Brusselton Hill to Stockton, at the rate of 1d. per ton for each mile, the rail-way dues being $\frac{1}{2}$d. and other expences $\frac{1}{4}$d. On the inclined planes 6d. per ton, in addition to this, is charged on each for the use of the machinery. Between Brusselton Hill, however, and Stockton, the way is free, and here the company, as we stated, are enabled to convey and to deliver coals into the ships on the Tees, at the rate of one penny per ton for each mile, or at 1s. 8d. for the whole twenty miles. On coals for land sale the dues are rather higher, and also on lime and other articles; but still the prices are very low, and such has been the effect in the market, that coals at Stockton, which for-

merly sold at 18s., are now selling for 8s. 6d. per ton. The above fact of the low price of carriage is really surprising, and we believe quite unprecedented in the annals of inland traffic; and had the execution of this railway done nothing else than to have ascertained and proved it, by its daily and weekly practice for nearly a twelvemonth together, it would have conferred a signal benefit on the country, and even on the nation. It certainly reflects the highest credit on the authors and promoters of the design, who, we understand, were chiefly belonging to the Society of Friends, and persevered in their plans under many difficulties and discouraging circumstances, but who may now look with satisfaction and pride on an act which does honour to themselves, their country, and the age in which we live. Coals, and, of course, other materials and goods, in the same, or nearly the same, proportion, may be conveyed to a distance, at the charge of one penny per ton for each mile. What a train of important consequences does not this single fact involve; and as this can be done in other places, what a wonderful field is thus opened for internal improvement. At present we are paying, on our best turnpike roads, as much as this, and more, for tolls alone, and six or eight times as much for all the expences of carriage. Coal, for example, from the vicinity of Dalkeith, costs in Edinburgh, which is only six miles distant, 4s. per ton for carriage alone, which at the above rates on the rail-way would amount to only 6d.; and coal imported at Leith costs 3s. 6d. per ton for the carriage up to Edinburgh, and as the distance is only two, or at most only two and a half miles, the carriage by the rail-way would cost only

$2\frac{1}{2}$d. Coal also from the Union Canal Basin costs 1s. 3d. for carriage to the centre of the town, the distance of which is scarcely a mile. Stone, again, for our buildings in Edinburgh, from the great quarries of Craigleith and Hailes, distant, the former two miles and the latter four from the centre of the town, cost respectively 2s. 2d. and 3s. 2d. per cart, or 2s. 8d. and 3s. 11d. per ton for carriage, while by the rail-way it would only come to 2d. and 4d. and any additional charge for carrying along the streets and delivery might bring it to 4d. and 8d. Between Glasgow and Edinburgh, one of our greatest thoroughfares, the carriage of such articles as are usually conveyed along that road costs some 1l. and others as high as 5l. and 6l. per ton; the average may run about 2l., and the distance being 44 miles, this is very nearly at the rate of 11d. per ton for each mile. Even canal navigation comes much short of the above standard of one penny a ton per mile. On the Union Canal, for example, coals shipped from Redding colliery cost at Port Hopetoun 4s. $6\frac{1}{2}$d. for the expences of transport, and the distance being 26 miles, this is at the rate of 2d. or double the expence by the rail-way. But the distance by the road is only 22 miles, and by a proper rail-way would be no greater; and this brings the comparative expence up very nearly to $2\frac{1}{2}$d. a ton per mile. On the Monkland Canal, again, in the neighbourhood of Glasgow, the distance from one of the coal pits to the Monkland basin is $10\frac{1}{2}$ miles, and the expence of transport 2s. 2d., which is at the rate very nearly of $2\frac{1}{2}$d. per ton.

Such then is the superiority of this new mode of conveyance, over every other that has hitherto been invented.

In our next paper we shall follow out the details, and in particular give a view of the advantages that would result to the public from a rail-way between Edinburgh and Glasgow.

RAIL-WAY

BETWEEN

EDINBURGH AND GLASGOW.

[EXTRACTED FROM THE CALEDONIAN MERCURY.]

In our last paper, we illustrated the economy of rail-way conveyance, as compared with our present roads, and even with canal navigation. In respect to the latter, we have another striking example in the conveyance of goods between Glasgow and Edinburgh through the Forth and Clyde and Union Canals; the expence of this runs from 15 to 24 shillings per ton; it may be averaged at 21 shillings; and the joint length of the two canals being nearly 57 miles, this is at the rate of 4½d. per ton for each mile; but if we take the distance between the centres of the two cities as it is by the Shotts and Bathgate roads, at 44 miles, this brings it up to 5¾d.; and yet it appears the Darlington Rail-way Company are conveying coal at the rate of 1d., and we see nothing to prevent the average of goods from being done at 2d. per ton for each mile, by which means the conveyance between Glasgow and Edinburgh might be reduced to 7s. in place of 21s. These facts are remarkable, and well worthy of attention. The traffic

between Glasgow and Edinburgh, and between the Forth and the Clyde, which lead immediately into the opposite seas, is so great, that a direct line of communication between them has been a long desired and much agitated project, and various lines of canal have been at different times surveyed, but none of them appear capable of effecting the object so simply and effectually as the rail-way. The distance between the centres of the two cities could not on it exceed 44 or 45 miles, and between the port of Leith and the shipping quays of the Broomielaw on the Clyde, 48 or 49 miles; but allowing 1s. 6d. for the use of inclined planes, or any other extraordinary charge on the line, still the cost of transport might be afforded at 7s., which would produce an immediate reduction of three-fourths of the expences by the roads, and of two-thirds of their amount by the canals. The consequences of this would be certain; a great proportion of the traffic between the two cities, as well as between the two seas, would naturally flow into this new and improved channel of communication. The annual expences of this trade at present cannot be estimated, we should think, at less than £150,000 or £180,000 a year. A saving therefore would arise of upwards £100,000 a year; and the effect of such an accumulation of capital, overflowing into new channels of profitable employment, would be astonishing. Some have doubted whether this scheme would pay its own expences, but the above facts, we should think, will set this matter at rest. It is not so much, however, the trade as it is at present carried on, that we are to look to; we may count with certainty on a vast increase from such an extraordinary reduction in the rates of conveyance. Look

at the important facts which are now passing under our eyes in the case of the Fife Ferries; the reduction of fares here in crossing the Forth, from 2s. and 1s. 6d. to 1s. and 6d., together with the advantage of more frequent trips, have, at the very outset, nearly quadrupled the intercourse on the passage. Besides this, the line of such a rail-way passes through a country rich in coal, ironstone, limestone, freestone, and other minerals. About 23 miles from Edinburgh, on this line, lies a most extensive coal field, known by the name of Benhar, containing seams of the finest quality, not inferior to the jewel coal of Mid Lothian. This coal is exactly in the situation of that already described in the county of Durham; it lies at no great depth, is hence easily worked, and only requires an opening to pour in an inexhaustible supply into our market. It sells at present, on the hill, at 5s. per ton; and, according to the Darlington rates, 1s. 10d. or say 2s. more, would bring it into Edinburgh, where it could thus be sold at 7s. per ton—the prices of the most inferior coal being now from 11s. to 12s. and of the best jewel coal from 15s. to 17s. In these circumstances, the consumption of the Benhar coal would be immense—it would either bring down the general prices, or acquire the complete ascendancy in the market; and as Edinburgh, exclusive of Leith, consumes 300,000 tons annually, it is but a moderate estimate, considering the increase of consumption which would arise from the reduction of price, to reckon 200,000 tons passing by the rail-way. This, at the rate of ½d. per ton of rail-way dues, for each of the 23 miles, would yield a revenue of about £9,500 a year, which alone would, at 5 per cent., pay an expenditure of £190,000. But on the

west end of the line also, and nearer to Glasgow, the line passes through and near to other very extensive coal fields, containing seams of great thickness, of excellent quality, and favourably situated for working. These are known generally by the name of the Glasgow Coal Fields, or the Coal Fields of the Clyde. They stretch along the banks and valley of that river, from the neighbourhood of Glasgow, for about twenty miles higher up, with an average breadth of eight miles. They occur in different seams, with various strata of stony and earthy substances interposed, all dipping towards the river on either side, until they approach the north and south extremities, where they wheel round, and mutually unite together, the whole forming one of those remarkable basins of mineral deposit which occur so frequently in our island, and afford, by the peculiar and admirably regular disposition of the strata, illustrations of the natural history and geological structure of our globe, at which even the philosopher pauses with curiosity and surprise. The whole district, comprehending an area of 160 square miles, forms an entire mass of coal, of which the aggregate thickness of the different seams varies from 12 to 30 feet. "Taking it all in all," say the mineral surveyors who were appointed to examine these districts by the subscribers to a canal, in the year 1794, "there are few such extensive coal fields to be met with; and so little of it has been worked, it can scarcely be said to have been yet begun upon." So that this store of mineral riches has hitherto lain dormant, owing to its distance from the great centre of business, the upper parts of it, where it could be worked with advantage, being distant from 10

to 15 miles from Glasgow. But it is in the power of art, we have seen, to conquer distance; and the rail-way would open up this treasure almost as if it had lain in the suburbs of the city. Glasgow consumes annually 600,000 tons of coal, and exports, besides, great quantities to Ireland, and these appear to be only limited by the present high price, which in Glasgow runs at from 9s. to 11s. per ton. The whole quantity at present raised in the collieries in the above districts, is between 700,000 and 800,000 tons; so that we may safely calculate on 300,000 tons passing by the rail-way. This, at ½d. per ton for each of the 10 miles of average distance for rail-way dues, would yield a revenue of upwards of 6,250l. a year; and adding this to the 9,500l. drawn from the eastern side of the line, we should have, for coal alone, 15,750l. a year; which, at five per cent., would cover an expenditure of 315,000l.—a sum which would go undoubtedly far to execute such a work, seeing that the Darlington rail-way, for 25 miles, with several branches, cost only 150,000l. Besides coal, the limestone and ironstone on the line would form valuable sources of revenue. Within 11 miles of Edinburgh, in the neighbourhood of Mid Calder, immense strata of lime rock occur, no less 40 feet thick. In one of the quarries belonging to the Earl of Morton the workings have never reached the bottom, which is supposed to lie at the depth of 60 feet. In the Glasgow coal fields again, according to the mineral surveyors, there are, at a considerable depth below the coals, "very rich fields of lime and iron stone intermingled, and alternately there is one limestone band, and many ironstone bands, as far as these fields have yet

been fathomed." Most of the iron, also, from the Shotts, Omoa, and Clyde iron works, and others, would pass along the rail-way. In short, whether we consider the extent and value of the thorough trade, and of the traffic from city to city, which this line of communication would engross, or the supplies of mineral, agricultural, or other produce which it would convey from different parts of its course to the great markets at either extremity, or the new and various branches of trade and business which would spring up along the line or in the two cities, in consequence of the new facilities of intercourse, and the cheapness of rude produce; such a work would not only become profitable to the undertakers of it, but of singular benefit to either city, as well as to the whole of the surrounding and intermediate country. And it is only, we have no doubt, owing to the late melancholy stagnation in trade, that this work, as well as others of a similar kind, which, as our readers are aware, were lately in agitation, have not been already commenced. The survey, however, we have recently understood, is completed, and, along with the engineer's report, will soon be printed, when we shall take another opportunity of describing more particularly the line of its direction, and various other circumstances connected with this great design.

The above facts, then, of the low price of land conveyance, lead, as we already observed, to a variety of important consequences. Hitherto the rail-way system has been viewed only as an auxiliary to inland navigation, or with a view to speedy travelling, and the conveyance of light goods.—But these place the subject in quite a new light. They prove that even for the conveyance of heavy goods,

where speed is not absolutely necessary, the rail-way is superior in point of economy, the speed of conveyance making up for any deficiency in the power of trackage. It has in every respect therefore the advantage, and must sooner or later become the principal medium of our inland trade. If, indeed, such reductions in the expences of carriage can be effected by means so simple, there is no doubt that these will speedily be adopted in all our great thoroughfares, and must supersede every other species of conveyance, where there is a carrying trade of any great consequence; besides opening up new and easy lines of communication throughout the country, and pushing the resources of trade and intercourse into districts hitherto shut out from their beneficial and all improving influence. And when we consider the immense sums now spent in accomplishing the active and busy traffic which is continually going on in the various districts of this great commercial country, and the heavy tax which it imposes on trade and industry, the consequence of such a revolution must be in the highest degree important. The saving on the expences of transport would be prodigious; and this, together with the increased facilities of intercourse, would give rise to an immense increase of business, while the most remote districts of the country would be explored, to furnish materials for our improving trade and manufactures, for the supply of an expanding population, and a rapidly increasing consumption of all the articles of convenience, luxury, and taste. Every branch of trade would participate in the general improvement, while new and innumerable sources of productive industry would arise for the employment of the various classes of our

people. In short, the whole community would feel an impulse of which it is impossible to calculate the effects; but should we live to see fully developed all the powers and energies of this system, we have no doubt it would prove one of the greatest benefits which philosophy or art have ever conferred on society.

But such is the extent and variety of discussion into which this subject has led us, that there is still one branch of trade on the Darlington rail-way which we have not touched on, and which is even more surprising and replete with important consequences than any other; we mean the conveyance of passengers and light goods. This we shall describe in another paper.

CONVEYANCE OF PASSENGERS AND LIGHT GOODS.

[EXTRACTED FROM THE CALEDONIAN MERCURY.]

Of all the advantages of the rail-way, the remarkable velocity of motion which it admits of, and which fits it so admirably for the conveyance of passengers, light goods, and mails, is the most striking and the most valuable, in a country where these objects are becoming every day of more and more importance. This property it derives from the original principles already explained, on which its efficiency depends, namely, the removal of all obstructions out of the way of the moving body. Could this be done entirely, it is evident that the facility of motion

would be perfect—the most enormous masses, so long as they continued on a level plane, might then be moved along the way with the smallest effort, and by a continued application of power their velocity might be increased without limit. Such perfection, however, can never be attained; for, independent of those gross and palpable obstructions which arise out of the rough materials of our common roads, there are still others arising from the friction and adhesion, even of the smoothest surfaces, which, as they are founded on the intimate nature and constitution of matter itself, it is impossible to remove. Let the natural roughness of bodies be ground down ever so smooth, still we experience, on drawing the one along the other, a resistance known in mechanics by the name of *friction*, and which may be reduced, but cannot be destroyed by the most elaborate polish. Even when, instead of drawing, we only roll the one along the other, although there is then no rubbing whatever, still we find a degree of resistance from the mere contact of the surfaces, which the smoothness of these may diminish, but cannot altogether remove. These resistances rank among the most remarkable phenomena in natural philosophy; the cause of them is quite unknown, but is justly ascribed, according to the ingenious theory of Professor Leslie, to some internal motions among the particles of matter, the nature of which, from their extreme minuteness, and our utter ignorance of the laws which connect these elementary atoms, and form them into a body, will probably ever remain concealed. All that we can do, therefore, is to diminish, as much as possible, these resistances, by smoothing the rubbing and rolling surfaces, both of the

carriages and of the ways, or by any other means which experience may suggest. Fortunately, however, there is one remarkable circumstance connected with these obstructions, which is highly favourable for the purposes of speed. It appears, from the experiments which have been made by various philosophers on the subject of friction, that it is nowise increased by the motion of the bodies themselves, however rapid this may be. Suppose, for example, a sledge is drawn along the ice at the rate of two miles an hour; then, according to these experiments, it follows that if it were drawn at four miles, at eight, at twelve miles, or at any other velocity, no increase would be felt in the resistance arising from the friction of the rubbing surfaces. This presents the same constant retarding force, whatever be the quickness of motion; so that when once this retarding effect is overcome, there is nothing but the mere inertia of the mass to prevent the body from being impelled with any velocity whatever. It may no doubt require a greater effort on the part of the animal to drag it with such velocity; but this arises not from any increase in the resistance arising from friction, but from the difficulty which all animals feel in increasing their own speed, and the cause of which is of the same nature as that already explained which retards a carriage on a common road. The animal advances not with a continued progressive motion, but with a sort of irregular hobbling, which raises and sinks its body at every alternate motion of the limbs. This is distinctly felt on horseback, and it is the same when the animal draws a load. Even in walking or running one does not move regularly forward. The body is raised and depressed at every step

of our progress; it is this incessant lifting of the mass which constitutes that drag on our motions which checks their speed, and confines it within such moderate limits; and it is this effect, and not any increase of friction arising from the velocity of the moving body which requires such efforts on the part of animals to increase the speed of their load even on the smoothest tracks. With machinery this inconvenience is not felt; the locomotive engine rolls regularly and progressively along the smooth tracks of the way, wholly unimpeded by the speed of its own motions; and this, independent of its economy, is one of the great advantages it possesses over animal power.—Such is the nature of that resistance to our motion along a rail-way, arising from the rubbing of the parts; but which is in all cases greatly diminished by setting the carriage on wheels, and thus confining the rubbing surfaces to the line of the axle and nave. Still, however, there remains the resistance arising from the rolling of the wheels along the way; and from what has been observed, this resistance appears to follow similar laws with the other. Experiments are no doubt still wanting on this point; but some have lately been made by Mr Wood, of Killingworth, author of a work on Rail-roads, which forms the best practical treatise on that subject which has yet been published; and we are informed by him, that, on rolling wheels down an inclined plane, loaded with weights to the amount of one or two tons, no sensible increase of resistance was observed from the speed of their motions, any more than in the case of friction itself. Whether we consider, therefore, the resistance on the rail-way, arising from the rubbing of the surfaces in contact, or from their rolling the one along the

other, they appear, by the laws to which they are subject, equally favourable for the purposes of speed. Obstructions they will always be in our way; but still, so long as they only present themselves in the shape of a constant retarding force, they can be easily overcome by the powers which nature and art place at our command. We have in them a certain determinate force of retardation opposing our motions; but in that case we have only to apply to our machinery a constant force of acceleration, of equal intensity. We have then force opposed to force, and a very small preponderance of power will be sufficient to impel the machine with any velocity that may be desired; at least with any velocity which it would be safe on other accounts to attempt. How different is the case in navigation. The fluid element supports, no doubt, and floats on its surface the most gigantic masses with admirable and perfect effect, and seems even to remove every obstruction to their motion, except mere inertia, such is the facility with which they roll, or can be moved about in any direction, by a comparative nothing in the balance of weight and power. This, however, is a mere deception. For no sooner does the vessel acquire any degree of velocity in the water, than the resistance of the dense medium becomes apparent. The obstructions to its progress seem to accumulate with every attempt that we make to urge her forward; and whatever amount of power is applied for this purpose, a limit of speed is soon attained, beyond which it becomes impossible to advance any farther. This is well exemplified by the tracking on rivers or canals. We there see the animal straining to its utmost, and yet continuing to plod at the same slow, yet weary and diffi-

cult pace, drawing no doubt an enormous load, but unable to advance it with any degree of speed. Even at sea, the power of the winds, let it be ever so strong, is incapable of impelling a vessel beyond a certain rate, which seldom exceeds ten or twelve miles an hour. There is something, therefore, in the nature of the fluid medium extremely adverse to rapid motion. It presents a resistance, not constant like friction, but continually increasing with the velocity of the moving body, and this even with an accelerated progression, which soon checks every attempt to get the better of it. The motion on a rail-way is subject to no such formidable opposition. The resistances here, on the contrary, are of such a nature as to become rather favourable to speed; for the quicker we move along the way, the less time is there for the retarding force to operate; by advancing, therefore, with rapidity, we escape in some degree from its influence, and may therefore be really impelled with a less amount of moving force, provided the machinery be adapted to move with the requisite velocity.

Such are the principles on which the operation of the rail-way depends for the rapid motions it admits of. Time and experience of its effects must no doubt be required to carry these principles fully into practice, as in all cases, and particularly one of such magnitude and importance, and requiring, as we have already stated, the aid of so many concurring circumstances, it is long ere the refinements of theory can be realised. Still the sure principles of science must in the end prevail, and give the railway, where speed is required, the decided pre-eminence

above every other mode of conveyance.* And it is satisfactory to find the operations of the Darlington rail-way, so far as they go, confirming by experience all these views of the subject. The following is the account of them:—Rail-way coaches are now plying regularly on the level part of that way, one between Darlington and Brusselton, which runs once a day and back again, and two between Darlington and Stockton, which run each twice a day and back. These coaches are each drawn by a single horse, and yet carry six passengers inside, and from fifteen to twenty outside, besides a due proportion of luggage, and run at the rate of ten miles an hour. The above seems an enormous load for one horse to run with, and at such speed; and yet to look at the animal, it appears to make scarcely any exertion, certainly not so much as a horse in a gig. It is only occasionally that he gives the vehicle a pull; at other times, even in ascending from Stockton to Darlington, the traces seemed to hang quite loose; and by far the greatest exertion appeared to consist in keeping up his own motion. The same horse which runs the coach down from Darlington to Stockton, brings it up again the same day. The coach consists merely of the body of a common inside and outside heavy coach set on a strong frame, with four wheels adapted for the rail-way, and considerably smaller than those of a carriage. The frame appeared too strong and heavy, and improvements

* These principles of friction and resistance have been long known among philosophers. But we are indebted to some able papers from the pen of Mr Maclaren, for calling the public attention to them, and explaining their various applications.

might be made on this as well as on other parts of its construction, which seemed far from being the most suitable for this new mode of travelling. The coach had no springs of any kind, and yet the motion was fully as easy as in any coach on the roads. A very slight jolt is felt, accompanied with a click or rattle, every time the wheels pass over the joints of the several rails, and also at the breaks which occur at the different passing places, and these, if any thing, feel harsher than in a coach, but in other respects the motion is fully smoother and easier, and with a set of good springs would far surpass any thing hitherto experienced on the best turnpikes. The coach never turns on the rail-way, but can be drawn either backwards or forwards with equal facility; the horse being merely unyoked from one side and yoked to the other, which is done in less than half a minute. To suit this arrangement, the front and back of the coach are made exactly alike, with the seats for the coachman, guard, and passengers, the same at either end, and the yoking place for the horse. Such is the extreme mobility of the whole vehicle and its load along the rail-way, that when once set in motion it is not easy stopping it; it is not enough here to "pull up," according to the coachmen's phrase; it requires an apparatus for the purpose, termed a brake, the operation of which is peculiar. It consists of a long arm or lever, turning on a centre between the fore and hind wheels at one side, reaching from thence up to the coachman's box, and having a short arm below, which, by moving the long one, can be made to press strongly on the rim of the wheels, and this creating a considerable friction, soon brings the carriage to rest. When the carriage is in

motion, the long arm of the brake rests on a hook under the coachman's seat; and when he wishes to check the motion of the vehicle, or to stop it altogether, the driver unlocks the brake, sets his foot on the extremity of the long arm, and pressing the short one against the wheels, this instantly checks the motion, and gives him the complete command both of the coach and the horse, let these be moving ever so rapidly. At any bends of the road, or other places where the view is obstructed, the coachmau blows a horn to give warning of his approach to any waggons or vehicles that may be coming or going on the way; and in meeting or passing, either the coaches or the vehicles go off into some of the passing places, and then return into the main line. On some occasions it happens, through inadvertence or other cause, that both coaches meet in a place between two passings, and when neither of them can get out of the way of the other: things seem approaching to a complete stand, when one of the coachmen unyokes his horse, reyokes him in an instant to the opposite end, and draws the carriage back to one of the passing places, which he enters, allows the other coach to pass, and then resumes his course. The whole affair is managed with surprising facility, and it is wonderful how little these obstacles, which appear at first sight very serious, really obstruct the progress of the traffic; although undoubtedly the true remedy is to have a double line of rails the whole length of the way. "It was on our way from Brusselton to Darlington," according to the journal of our informant, "that we met the Express coach coming up, and which was viewed with much interest, being the first of the kind we had ever seen; it was well loaded, having sixteen outside, and six inside passengers; it was

drawn by one little pony, and seemed to be going at the rate of nine miles an hour. Next day we mounted, ourselves, on the top of the Defence coach, and started from Stockton, highly interested with the novelty of the scene, and of this new and extraordinary conveyance. Nothing appeared more surprising than the rapidity and smoothness of the motion, considering that the coach had no springs; and also the ease with which the animal drew his load. Most of the way is laid with rails eighteen feet long, and here the only irregularity in the motion arose from the joinings of the rails, at each of which the coach gave a very slight jerk. This, however, we have no doubt, will be greatly reduced, if not entirely removed, by an improved mode of joining the rails, which has since been introduced, and consists in lapping the one over the other at the joints. Some parts of the way were laid with rails of cast iron, joined at every four feet, and in coming upon these, the difference of motion and of feeling was quite remarkable. The jerks and jolts, in passing over the joinings of the rails, were more frequent, more audible, and more sensible, resembling exactly, as the coachman justly observed to us, the clinking of a mill hopper; and the whole motion was more irregular and harsher than before, although still far more easy than in a similar vehicle on a common road. Nothing, however, demonstrates more clearly the advantage of long rails and few joinings, and the importance of forming these with all the accuracy which can possibly be devised. We left Darlington with thirteen outside passengers, and two or three inside, and picked up various others on the way. In regard to passengers, the coach appears to be no way

limited in its numbers. The coachman informed us that one day lately, during the time of the Stockton races, he took up from Stockton nine inside and thirty-seven outside, in all forty-six. Of these some were seated all round the top of the coach on the outside, others stood crowded together in a mass on the top, and the remainder clung to any part where they could get a footing. On that occasion he had two horses. We started from Darlington at 14 minutes past eight, and arrived at Stockton at 35 minutes past nine, making the journey of 12 miles in one hour and 21 minutes, including 11 minutes at least spent in taking in and letting off passengers. This is fully at the rate of 10 miles an hour. But on comparing the speed in different parts of the way, which is easily done by means of posts which are erected at every quarter of a mile, we found it frequently as high as 14 miles an hour. We again left Stockton at 12 minutes past one, with 15 outside passengers and two or three inside, and arrived at Darlington at 25 minutes past two. The fare for outside passengers is only one shilling for the whole twelve miles, and for shorter distances at the rate of one penny per mile. The inside fares are exactly double of this."

Such, then, is the first great attempt to establish the use of rail-ways for the general purposes of travelling, and such is the success with which it has been attended, that the traffic in this way is already great; and, considering that there was formerly no coach at all on either of the roads along which the rail-way runs parallel—quite wonderful. A trade and intercourse has arisen out of nothing, and nobody knew how. It was unlooked for even by the promoters of the rail-way themselves, who now draw at the rate

of £400 or £500 a year for the coaches alone; and, altogether, the circumstances of bustle and activity which now appear along the line, with the crowds of passengers going and returning, form a matter of surprise to the whole neighbourhood as well as to the public. In our next article we shall conclude the subject of rail-ways, by illustrating the importance of these facts, and going into details of their application, particularly to the conveyance of the mails between Edinburgh and London.

NEWCASTLE:
PRINTED BY EDW. WALKER.